What About Watts?

Solar modules only produce their claimed output under 'Standard Operating Conditions'. These have little resemblance to user reality. In a typical small 12/24-volt system most modules produce about 70% of that apparently claimed. Here's why. Module output is quoted in watts. One watt is defined as one amp multiplied by one volt, so to produce 80 watts a module operating at 12 volts must, by definition, produce 6.66 amps. In practice it produces about 4.6 amps - and 4.6 amps X 12 volts is only 55.2 watts. The difference is due to a curious rating that is based on whatever combination of voltage and current gives the highest number - regardless of whether the module can actually be used at that voltage. Most modules produce up to 21 volts, with maximum current occurring around 17 volts. Multiply 17.1 volts by those 4.6 amps and there's the 80-watts claimed. But because there are also losses due to heat you'll only get this on top of an equatorial mountain on a cold day around noon.

Influences on Solar Power

Sunlight

Solar irradiation is measured in Peak Sun Hours (PSH). The concept is like that of a rain gauge in that fluctuations are averaged: replace rainfall by sunlight and you have the general idea. With three-way fridges, solar is practicable at 2 PSH. With an efficient chest fridge it becomes practicable at 3 - 3.5 PSH. For a medium-sized door-opening electric fridge you really need 4 PSH. It's also advisable to have generator back up.

Heat

All but amorphous technology (eg. Uni-Solar) modules lose about 5% output for every 10 degrees C increase above a cell (not ambient) temperature of 25 degrees C. On a moderate 25 degree day another 10% has gone. At 35 degrees C it's 15%. Then, that '80-watt' module produces about 50 watts. Amorphous modules increase output slightly as they warm up, but they are hugely larger than anything else so this is only of value where it's hot and there's plenty of room. Modules carry a rear sticker that reveals all this. Unfortunately it's in techno-speke.

Shadow

No modules work in full shade, but they differ a lot when partly shaded. Most lose nearly all output if only a small area is shaded. Amorphous modules lose output proportional to the area shaded. For the highest average output modules must face the sun but, except for lower latitudes, flat mounting loses only 10-20%. Compensate by adding 10/20% more capacity - tracking is complex and not worth the effort.

Solar Power Components

Solar Panels

Solar power is the technology of obtaining usable energy from the light of the Sun. Solar panels, which are typically found in commercial, residential and camping environments, are the components that captures this energy. A solar panel refers to a photovoltaic module which is an assembly of solar cells used to generate electricity. These panels are generally flat, and are available in various widths and heights.

Batteries

A lead acid battery is charged by applying a voltage greater than it already has. The higher that applied voltage, the heavier the charge. If the charging voltage is fixed, as the battery charges and its voltage rises, charge rate automatically falls. Vehicle alternator/regulators (and cheap battery chargers) work this way and, with the former at least, charging tapers almost to zero once the battery is 70% 'full'. This prevents overcharging with vehicles like taxis on shifts.

This partial charge is not a problem for starting because the starter motor is designed accordingly. Unfortunately, 'house' batteries charged by the same system are likewise limited to 70%, and may take forever to reach even that (battery makers say that, with trailer batteries, 65% is more common). You cannot even access all of that 70% charge because even deep cycle batteries are progressively damaged if regularly discharged below 50%. If you follow their makers' advice only 15%-20% of nominal battery capacity is available for use! Discharging down to 40% (about 12.1 volts on a well-rested battery) is a reasonable compromise, but many people routinely run batteries close to flat. If you do that however, even a top quality battery is wrecked within 100 such cycles of such abuse.

Fortunately, damage is limited to your bank balance as appliances damageable by low voltage are protected against it internally. There are ways of charging more deeply, and this can virtually double the safe usable capacity.

A 'smart' alternator regulator and upgraded alternator will charge batteries close to 100% within two/three hours driving. Few are compatible with computer engine management systems but they are great for older vehicles and non-computerised diesels. Another solution is gel cell or AGM batteries. Both charge fully and rapidly from standard vehicle alternators. They can also be discharged more deeply and with less damage. Their makers warn not to charge them in parallel with standard batteries - but many do. (More about Battery Power)

Yet another solution, and one that I strongly recommend following the advent of compact high wattage modules, is charging (house batteries) from solar alone. This is simple and works very well, not least because they can be charged via an optimum regime. The best way of all is to keep them over 80% charged nearly all the time.

Solar Regulators

Solar regulators ensure that charging is speedy and safe, meanwhile protecting batteries against overcharging, and appliances against over-voltage. With a solar regulator installed, it is safe and beneficial to leave batteries on permanent charge - but check electrolyte level at least every 8-10 weeks. Some claim solar regulators are unnecessary - but it's odds on their system is so badly designed/installed that even omitting the regulator makes little further odds!

I met one character who had four 80-watt modules, but no regulator, connected to a small Engel fridge via 60 metres of 1.5 amp lighting cable. The fridge had 11.6 volts across it. It could barely cool a can of beer. Replacing the cable by a 10-metre length of twice the size enabled the fridge to freeze a tinnie using just one module. But then, with the batteries now literally boiling to death, this bloke still insisted regulators were unnecessary! Solar regulators cost $70 upwards. The more costly variety (>$300) tell you what the system is doing.

Energy Monitoring

Instantaneous measurement of deep cycle battery voltage is meaningless and often leads to quite wrong conclusions: all you can really be sure of is that the meter's working. After brief engine running, a battery that's almost flat may measure close to fully charged. A close to fully charged battery may measure as 'flat' after running a microwave oven for a minute or two.

A hydrometer reading is better because this checks the electrolyte directly but is of course not possible with sealed batteries. If you must check voltage, do so first thing in the morning before anything is switched on. But there may still be 15%-20% error. The only meaningful measurement is to check what goes in and what comes out - and deduct a bit for system losses. What's left is more or less what you've got.

Such energy monitoring is built into upmarket solar regulators. Without monitoring, you risk wrecking your battery through constant undercharging and/or over-discharging. Over-charging is less common but occurs. It is usually caused by leaving a battery across a poor quality battery charger too long.

Calculating Energy Requirements

Establish Energy Draw

The first thing to do, is to establish the typical daily energy draw for the appliances that you will be using.
There is a brief guide of appliances in the section titled "Typical Energy Draw".

Establish Peak Sun Hours (PSH)

Next thing is to establish the probable peak sun hours and then calculate the module capacity for the daily energy draw. You should also add approximately 15%-30% extra to ensure speedy recharging. Now if you assume more than 4 peak sun hours per day, install oversize cabling and a solar regulator to allow for possible additional solar capacity. You may end up not needing it, however, it's quite difficult and costly to do it later.

Example: (Corrected) usage = 350 watt/hours/day. Assumed input = 3.5 PSH/day. Required solar capacity in watts is thus 350 divided by 3.5. That's a true 100 watts - or about 135 'nominal' watts.

Adequate Battery Capacity

The adequate capacity for batteries is 250 - 350 amp/hours. Don't have more battery capacity than you can speedily re-charge. A maximum of three to four times daily solar input is practicable for mobile self-sufficient systems. More is not necessarily better.

Example: Two 120-watt modules typically operating with 5 Peak Sun Hours/day will produce about 180 X 5 watt/hours/day (900 watt/hours/day). Establish the typical daily energy draw (in watts).

For supplementing battery energy, use the brief guide of appliances in the section titled "Typical Energy Draw".
Calculate the available battery capacity from an initial 70% charge to whatever discharge level you feel acceptable.
To convert to watts, multiply amp/hours by 12.) If this exceeds 40% of nominal battery capacity you will be buying new batteries sooner than expected. Divide available battery capacity by the number of days you want to stay on site. From your probable daily usage (calculated from the appliance guide), subtract the daily battery energy available. Whatever the difference, that's the amount you must find each day. From actual module output work out module capacity you need to provide that difference. It's well worth doing the above sums for both methods. Once you go past an intended five days on site it costs only a little more to have a totally self-sufficient system.

A New Way of Thinking

The traditional approach is to add a solar module or two to eke out diminishing battery energy: batteries still run down, only a bit later. A better way is to have enough solar capacity to be electrically independent (ie. at least as much energy comes in as goes out). This way batteries remain close to fully charged nearly all the time. They charge close to 100% by mid-day or early afternoon, dropping to 85% or so overnight. This requires about 20%-30% more module capacity but, if money's tight, you can reduce battery capacity. In the long run you may end up ahead because the batteries last much longer.

Working out Watts Needed

Typical Energy Draw

The points below show typical energy draw for various device types. These figures are measured in watts.

- Cassette/CD player - 30
- Coffee grinder - 30
- Computer (laptop) - 20 to 50
- Computer (desktop) - 300 to 500
- Computer printer (ink jet) - 40 to 70
- Fans (12/24 volt) - 10 to 25
- Fans (240-volt) - 30 to 100
- Food mixer - 350 to 450

- Juicer - 350
- Lights (compact fluro) - 5 to 18
- Lights (halogen) - 10 to 50
- Macerator - 300 to 350
- Microwave oven (‘800-watts’) - 1350*
- Radio - 5 to 15
- Sewing machine - 75 to 100
- Stereo - 50 to 60
- TV (10-14 inch) - 20 to 50
- TV (16-20 inch) - 60 to 100
- VDC/DVD - 30
- Washing machine - 350 to 600

- Water pumps (12/24 volt) - 50

Typical consumption of electrical equipment.
* For microwave ovens run via an inverter - add 15%

Allowing for Inverter and Battery Loss

The points below show typical daily consumption while also allowing for inverter and battery losses.
These figures are measured in watt/hours/day.

- Trailer/small caravan/campervan with three-way fridge - 130 to 175
- As above with 4-70 litre electric chest-opening fridge - 450 to 550
- Medium caravans/small motorhomes with three-way fridge - 350 to 450
- As above with 110-130 litre electric only fridge - 1100 to 1250
- Large caravans/medium motorhomes with three-way fridge - 450 to 600
- As above with 110-130 litre electric only fridge - 1200 to 1400
- Large motorhomes with three-way fridge - 500 to 600
- As above with 220-litre electric only fridge - 1700 to 2000

Note: For every example of above, add a further 30 watts for every minute that a microwave oven is in use. This table dramatically illustrates the huge savings effected by using a three-way gas/electric fridge.

Solar Power and Appliances

Fridges

An electric-only fridge gobbles 60%-80% of daily electrical draw. Chest-opening types are the most efficient; door-opening types use more power. A realistic maximum is 170 litres. This will need three (ideally four) 120-watt modules. If money is tight a better choice may be a Domestic Climate Class 'T' three-way fridge. These fridges run on 12-volts whilst driving, 240-volts where mains is available and gas at all other times. The 'T' indicates the fridge is designed to run in ambient temperatures up to 43 degrees C. Use this type of fridge and you may need only a single 120-165 watt module (see later for specifics). All fridges must be installed correctly to work as intended. Most are not - and hence don't. Cooling performance can be hugely improved via simple changes.

Microwave Ovens

A microwave, via an inverter, draws more energy than you assume. That rated wattage is the equivalent heat it produces - not the energy drawn. An '800-watt' microwave may draw 1500 watts (around 125 amps at 12 volts). Ten minutes usage may draw a day's output from a 64-watt module. Use a microwave only where there's mains power.

Lighting

The most efficient lights are fluorescent tubes and compact fluorescent globes. Some have inbuilt inverters for 12-volt connection. You can use 240-volt fluros via a separate inverter but this necessitates mains-voltage wiring. White LED lights draw little power, mainly because they give little light. But that light is tightly focussed so they are good for reading and, (in headband form) for campfire cookery. But right now, not for general lighting. Recently introduced, cold cathode lights are even more efficient but take five/ten minutes for full brightness. Twelve-volt halogens use twice the energy of fluorescents (half that of incandescent) but run very hot. They can be uncomfortable if close overhead.

General

Consider only gas for cooking and heating water. Solar is not feasible for any major heating application. Water pumps need to be 12-volts - ditto cooling fans. TVs, VCRs and DVDs are only a problem if used for hours on end. If you really need a computer use a laptop.

Installing the System

Firstly I warn of a HUGE trap. It even catches those who know about electrics. It concerns the way cables are rated. Unless you know about it, you are almost certain to use cable less than half the size required. If you do this you will have built-in a fault that will plague you and future owners for years to come.

Cable Ratings

Cable ratings cause this havoc because few people know there is a problem. But believe me there is! Electrical appliance makers and electrical engineers worldwide (except in the USA) specify cable by the cross-sectional area of its copper core (in square millimetres). Americans mostly use American Wire Gauge (AWG) and if you use it there's no problem. Most countries however use so-called auto cable so when you set out to buy the 3.0, 4.0 or 6.0 sq.mm. cable that the appliance maker specifies, what you will almost certainly be sold is 3.0, 4.0 or 6.0 mm auto cable. Unfortunately (to use a massive understatement), for reasons that totally defy sanity, auto cable makers use similar numbering to indicate something quite different.

An auto cable vendor's 4.0 and 6.0 mm is not a measure of the copper core that carries the current. It is the diameter of the hole the cable will pass through! As a result, 3.0 mm auto cable is about 1.0 sq mm; 4.0 mm auto cable is about 1.8-2.0 sq mm; and 6.00 mm auto cable is about 4.6 sq mm. It can only be 'about' because auto cable 'rating' includes the thickness of the insulation. Whilst overall diameter stays the same, the ratio of copper/insulation varies from brand to brand -usually decreasing with price because plastic is cheaper than copper. (Some but by no means all auto cable has the sq. mm. data (in small type) also on the drum. It is usually also in the technical literature. You can substitute 6 mm auto cable (typically 4.59 sq mm) for 4.00 sq mm cable, and 4.0 mm auto cable for 1.5 sq mm. Apart from 8.0 mm auto cable, which really is 8.0 sq mm; these are the only 'safe' conversions. Auto cable smaller than 3.0 mm has so little copper you may as well use wet string.

What to Ask For?

Few if any auto parts stores understand or are even aware of this issue. Ask for 4.0 sq. mm. cable (or even spell that out) and you are almost certain to be sold 4.0 mm auto cable (that is 1.8-2.0 sq mm) - because that's the only cable they know of and sell. If you have used this cable (and if you have done any vehicle wiring it's odds-on you have) you are likely to have voltage drops at least twice that acceptable. Energy will be lost as heat and things connected to those cables (especially 12-volt fridges) will not and cannot work as intended. Lights will be dimmer, motors will run slower, produce less power, and overheat. But fridge cooling in particular is dramatically reduced.

Current Ratings

Auto cable is also 'rated' as '30 amp' - '50 amp' etc. This is a fire rating only. It provides no meaningful guide to usage, nor indication of voltage drop. It is merely a guide to the maximum current that cable can carry before the insulation begins to melt. If you understand all this and choose cable accordingly, auto cable is just fine. It is usefully flexible and smaller than its 240-volt equivalent. But the rating method is misleading beyond belief. Very high quality tinned-copper cable in square millimetre ratings can be obtained from specialised marine electrical suppliers. Another way is to use 1.5 mm and 2.5 sq mm multi-strand 240-volt lighting and power cable.. Don't use so-called 'building cable'. It is insufficiently flexible.